SCIENCE

NEW SERIES
VOL. XLVII. No. 1203

FRIDAY, JANUARY 18, 1918

SINGLE COPIES, 15 CTS.
ANNUAL SUBSCRIPTION, $5.00

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PRESENT TENDENCIES IN THEORETICAL PHYSICS[1]

AT a time like the present, when the minds of all of us are intent upon the war and the great issues which depend upon it, it seems almost an affectation to discuss before you a subject so remote from "the instant need of things" as the methods and outlook of theoretical physics. The custom of many years, however, constrains the sectional vice-president to deliver an address. The many questions raised by the war and the relation of science to war have been so thoroughly discussed that I should certainly not be justified in inflicting upon you at great length my own views. The only alternative, therefore, to an appearance of detachment, which I am far from feeling, would have been the abolition for this year of the vice-presidential address before Section B—a measure of war-economy which would have commanded my hearty and unqualified support.

When, however, we turn our minds to a consideration of the recent development of our science, we are confronted at once with the unmistakable fact that there has been little progress since August, 1914, in either theoretical or experimental physics. We had become accustomed to a steady succession, year by year, of important experimental discoveries and of ingenious and original theoretical discussions; we need mention only a few—the Stark Effect, the crystalline diffraction of X-rays, Onnes's

[1] Address of the vice-president and chairman of Section B—Physics—American Association for the Advancement of Science, Pittsburgh, December, 1917.

superconductivity, Debye's theory of specific heats, the Rutherford nucleus atom, the existence of chemical isotopes, Bohr's theory, Moseley's law, Einstein's theory of gravitation. I do not recall anything comparable with these in interest and importance which has appeared during the past three years. Whatever services science may render to war, it is plain that a state of war is not favorable to the progress of science. Accordingly, the word "present" in my title must be interpreted with some latitude; it really applies to the state of things before the peaceful labor of physicists was interrupted by the duty of turning their attention to problems in applied science whose solution is of immediate urgency.

No one can doubt that there has been something very like a revolution in the ideas and methods of theoretical physics since the beginning of the twentieth century. Much recent work of undoubted significance would seem very strange to Helmholtz and Lord Kelvin; and even in some of our own contemporaries whose tastes are conservative, it excites feelings similar to those experienced by a Royal Academician before a cubist painting. On the other hand, some of our younger and more enthusiastic colleagues are inclined to be impatient of what they call "classical" theories (some of which were perfected in the 1890's), and to regard them as examples of superstition and logical punctilio from which they have been happily freed.

The truth is of course to be found between the two extreme views. We must recognize that this is not the first change in physical science which has seemed at the time to be revolutionary. In the past, these changes have never been so complete and overwhelming as was expected by their supporters, nor so abortive as hoped by their opponents. In science, as in art, politics and religion, the radicals are always partly right and the conservatives never wholly wrong; and the interplay and conflict between the two is of the very essence of progress.

One of the most striking things about the modern beginnings of our science—the preliminary formulation of the principles of mechanics by Galileo, and their more complete development by Newton—was their almost immediate acceptance by all who were not blinded by theological prejudices. This can not have been because they were simple or easy to formulate, or the world would not have had to wait so many centuries for them. But the phenomena of mechanics are directly and explicitly presented to us from our earliest childhood, and have been so presented to our long line of ancestors, human and pre-human. Under given conditions, certain mechanical actions are almost as confidently expected (even by quite uninstructed persons) as if their knowledge was of the *a priori* character that is attributed by many philosophers to our mathematical and spatial concepts. Even animals share this mechanical knowledge. The instinctive movements of a cat, which enable it to land upon its feet, could scarcely be improved upon if it possessed a satisfactory knowledge of the conservation of angular momentum. The difficulty of formulation was doubtless due to the lack of recognition of the true character of frictional and dissipative forces, and to the obscuring of the idea of mass by the more conspicuous property of weight. At all events, when the principles are once presented to the normal, intelligent, observant mind, they are quickly recognized, and soon come to seem almost as axiomatic as the attributes of space and number. There can be little doubt of the reality of this mechanical "intuition," be its origin what it may. Whatever the philosophers

may think of it in their moments of sophisticated philosophizing, there can be no doubt that they, in common with less instructed people, have a feeling of satisfaction and intellectual rest when an adequate mechanical "explanation" is given of some natural phenomenon.

Newton, with the characteristic boldness of genius, extended the Galilean mechanics of earthly matter to the heavenly bodies, and (as often happens) found in the remoter phenomena better and more complete confirmation of his theory than in the nearer and more obvious manifestations. With the single additional assumption of the gravitational force, all the intricate wanderings of sun, moon and planets in the celestial sphere fell into a system—simple, orderly and in accord with our commonest experiences of every-day life. It is not surprising that to all minds capable of understanding it, Newton's theory carried instant conviction.

Nature and Nature's Laws were hid in night,
God said, "Let Newton be," and all was light.

But the law of gravitation did not enjoy the same independent status in the minds of natural philosophers; from that day to this they have been under temptation to find what we all call an "explanation" of it, while few if any have ever felt the necessity for an explanation of the laws of motion. Newton himself, in the "Opticks," speculates as to a possible ethereal explanation of gravitation; and even in the celebrated passage at the end of the "Principia," in which he renounces hypotheses, the context shows, I think, that he felt strongly the desire for an explanation, but was compelled to forego it because "hitherto I have not been able to discover the causes of those properties of gravity from phenomena."

The century following Newton was devoted to the development of mechanics and of gravitational astronomy and culminated in the great achievements of Lagrange and Laplace. There was some discussion as to the relative merits of action at a distance and *vis a tergo,* and some direct attempts to account for gravitation on the latter basis—notably that of LeSage early in the nineteenth century. But, on the whole, the opinion gained strength that Newton had been right in his view that there was little hope of being able to test such theories by comparison with "phenomena."

The discovery by Coulomb that magnetic and electric forces conformed to the Newtonian law gave strength to the prevalent opinion that this law was fundamental in the constitution of the physical universe. The mathematical technique of the subject was highly developed and there was a growing tendency to explain observed phenomena by distance-forces between particles, rather than to seek a more strictly dynamical theory to account for such forces. This procedure was certainly defensible upon philosophical grounds, and proved its utility in many problems of mathematical physics. It was the prevailing fashion in the early part of the nineteenth century.

Thus it was entirely natural that Ampère, when he heard in 1820 of Oersted's discovery, should have based his investigation of electrodynamics upon the Newtonian model, by using current-elements acting upon each other by forces in the line joining them. Again the law proved to be that of the inverse square; but the fact that the attracting elements were directed quantities added many difficulties which, in the state of mathematical science at that time, gave ample scope to the "Newton of electricity" for the display of his genius. These vector relations involve an indeterminateness which later gave rise to many rivals to Ampère's theory; other expres-

sions for the forces between elements gave the same results when integrated around closed circuits, and no one succeeded in devising experiments which would discriminate between them. Even Ampère, however (like the great predecessor whose name Maxwell connected with his), was not immune from the inherent desire of the physicist for "explanations" of distance-forces, though he was compelled to forego them because no way appeared for putting them to an experimental test. At the beginning of the memoir,[2] in which he sums up his electrodynamic researches, after declaring his adherence to the Newtonian procedure and renouncing anything in the nature of Cartesian vortices which Oersted's discovery had in a measure revived, he says:

> I have made no attempt to find the cause of these forces, well persuaded that any attempt of this kind ought to be preceded by the purely experimental knowledge of the laws and by the determination from these laws alone of the value of the elementary forces, whose direction is necessarily that of the straight line drawn through the material points between which the forces act.

Later in the same memoir[3] he disclaims any intention to assert that his forces are to be regarded as "truly elementary" and calls attention to previous attempts of his own[4] to "assign a cause for these forces in the reactions of the fluid filling all space whose vibrations produce the phenomena of light."

Simultaneously with these developments and partly in consequence of some of them, the employment of imponderable fluids became very general in theoretical physics. In electrostatics and magnetism, the gravitational analogy required some sort of attracting or repelling substance; in the theory of heat, the calorimetrical experiments of Black and his clear discrimination between temperature and quantity of heat, led directly to a substantial theory of heat. There was no great encouragement for the attempt to apply the principles of mechanics to these imponderables; so far as experiment showed they lacked not only the conspicuous property of weight, but also the most essential dynamical characteristic of ordinary matter, viz., inertia. The natural and fertile method of dealing with them was to take some empirical relations, as simple and fundamental as possible, as postulates for the mathematical development of the subject. Some of the most epoch-making advances in theoretical physics are instances of this method; as examples one needs only to recall Fourier's theory of heat conduction (afterwards applied by Ohm to the conduction of electricity), and Carnot's deduction of the theory of heat engines from the empirical principle which we now call the second law of thermodynamics. In fact, the great physicists who flourished during the first three or four decades of the nineteenth century seem to have felt that there was little hope of giving dynamical explanations of all physical phenomena. Thus Fourier, in the introduction of his great work, recounting the glorious achievements of Newton and his successors, says:

> It is recognized that the same principles regulate all the movements of the stars, their form, the inequalities of their courses, the equilibrium and oscillations of the seas, the harmonic vibrations of air and sonorous bodies, the transmission of light, capillary action, the undulations of fluids, in fine the most complex effects of all the natural forces; and thus has the thought of Newton been confirmed; *quod tam paucis tam multa præstet geometria gloriatur.*

"But," continues Fourier, "whatever may be the range of mechanical theories, they do not apply to the effects of heat.

[2] *Mem. de l'Acad.*, VI., p. 177 (1825).

[3] P. 294.

[4] "Recueil d'observations electro-dynamiques," p. 215.

These make up a special order of phenomena which can not be explained by the principles of motion and equilibrium." His attitude may fairly be taken as, in general, characteristic of his time; there were sharp lines of demarkation between the different departments of natural philosophy which would doubtless cause feelings of surprise and discomfort to a modern physicist if he could suddenly find himself at a meeting of the Royal Society or of the Paris Academy in the year 1822. These barriers were to a considerable extent broken down in the forties by the discovery and development of the principle of the conservation of energy. It was not simply the quantitative relation which excited the enthusiasm of the men of that time, but the knowledge that there was a "correlation of Physical Forces"; their reception of the discovery shows how much such a relation had been wanted.

The psychology of physicists made it inevitable that energy should be regarded as something more real than a mathematical expression which remains constant during various processes. It was given a quasi-substantial interpretation and localized in space; and it was most natural that its newly recognized forms should be identified as nearly as possible with the familiar energy of ordinary mechanics. Thus we had at once a *mechanical* theory of heat which led to a great extension of molecular hypotheses; and the desire to deduce the empirical second law from dynamical principles was the motive for the development of statistical mechanics through the successive stages shown in the work of Maxwell, Boltzmann and Gibbs.

This tendency toward dynamical explanations was strengthened by the progress of the wave-theory of light. After the brilliant experiments and interpretations of Young and Fresnel it was impossible to doubt the kinematical similarity of light to a transverse wave motion. This made it necessary to postulate an ether and to give it suitable properties; the theory of waves in an ordinary material elastic solid was developed by Green, Cauchy, Thomson and others and compared with the phenomena of light. The lack of complete agreement was a stimulus to the investigation of other possible types of elastic substances conforming to the general laws of mechanics. In the hands of MacCullagh, Stokes, and especially of Kelvin, these investigations led to great advances in our knowledge of the properties of continuous media, and showed the dynamical possibility of the existence of media which were quite different in their elastic properties from ordinary matter.

Another current of thought which influenced profoundly the complex development of theoretical physics in the nineteenth century was the strong prejudice of Faraday against action at a distance and his instinctive preference for a mode of representation which involved the transfer of forces from point to point by the interaction of contiguous parts of a continuous medium. The fertility and usefulness of this method in electromagnetism is attested not only by Faraday's unparalleled success as a discoverer (for genius choses the method best suited to itself), but also by the fact that it has held the field in elementary instruction as well as in the most complicated applications of electrical engineering. We all know how Maxwell deliberately submitted himself to the influence of this prejudice, and the epoch-making result which followed from its union with his mathematical skill. The inclusion in a single theory of two great bodies of phenomena, those of light and those of electricity, was an achievement of

the first magnitude and an immense stride in the direction of the unification of natural causes. But it did not satisfy the thoroughgoing dynamical prejudices of Lord Kelvin, who insisted to the end of his life that he did not "understand" the electromagnetic theory and that it "has not helped us hitherto." Maxwell himself was scarcely less desirous of finding a dynamical foundation for his theory. In fact, its first form was a detailed mechanical model of vortices and idle wheels; in the final form details were avoided by the use of the generalized dynamics of Lagrange and Hamilton, and Maxwell succeeded in showing that certain parts at least of his theory could be based upon dynamical principles.

This use of Lagrangian and Hamiltonian methods in the investigation of physical phenomena was a new weapon in the hands of those who sought to reduce them all to a dynamical basis. It has been used with effect by J. J. Thomson, Larmor, and (in application to statistical mechanics) by Gibbs. It makes feasible the ultimate refinement and completeness of dynamical explanation; in place of the potential energy in the Lagrangian function we may substitute the kinetic energy of concealed motions and thus the last vestige of unexplained distance-forces may be swept away.

The most thoroughgoing and successful example of this method is the very comprehensive theory of the physical universe contained in Larmor's "Æther and Matter" published in the last year of the nineteenth century. His ether is identical with MacCullagh's rotationally elastic medium; it has imbedded in it centers of rotational strain (the electrons), out of which the atoms of matter may be built up. The only assumptions are that the positive and negative electrons are somehow prevented from destroying each other and that they, with their fields of strain, are capable of motion through the fixed medium. From Hamilton's principle, the Maxwellian equations for the free ether are deduced and, in the presence of matter (electrons), whether at rest or in motion, the same relations hold as those found experimentally. The rotational elasticity of the medium may be produced gyrostatically, so that the potential energy may, if one chooses, be replaced by kinetic. It is interesting to observe that the position, velocity and momentum of a material particle, in this theory, are really Lagrangian, generalized values. The motion of the centers of strain (*e. g.* in a straight line) cause a slight twisting and untwisting motion of the ether where the true mass and momentum reside. Thus the apparent mass of Larmor's electron varies with its speed as that of cathode rays was afterward found to do; but its dynamical orthodoxy is as sound as that of a steam-engine governor, whose moment of inertia varies with its angular velocity.

Notwithstanding the triumphs of the dynamical school of thought, its assumptions and methods were subjected to searching criticism on philosophical grounds particularly by Kirchhoff and Mach. In Kirchhoff's "Lectures on Mechanics," published in 1876, he explicitly renounces the attempt to find the causes of natural phenomena or to "explain" them in the traditional sense; the purpose of mechanics itself (to say nothing of the parts of physics more remote from common observation) is simply the description of phenomena. Forces as *causes* of motion are rejected; they are merely convenient abbreviations for certain functions of observed motions. In the first lecture he points out that Newton by no means discovered that the force of gravitation was the cause of the motion of the planets which Kepler had described; he only

showed that the description was simpler and briefer if expressed in terms of the second differential coefficients instead of the first. Similar ideas have been developed with greater generality by Mach, who finds the final purpose of scientific theories to be economy of thought, and classes the search for causes, explanations and dynamical theories, among the metaphysical prejudices which hinder the progress of science.

The criticism of Kirchhoff and Mach is logical and convincing. No unprejudiced person can doubt that, after a discovery is made, it may be interpreted in their way and that, on the whole, this interpretation is the cleanest, most rational and most free from human weakness. But from the pragmatic point of view, and in the light of experience of the course of science in the past, it may well be doubted if their attitude of mind is a useful one in the work of investigation and discovery as distinguished from subsequent criticism and clarification. A somewhat extreme example of militant advocacy of the descriptive method was furnished about twenty years ago by the school of energetics under the leadership of Ostwald. Any use of atomic hypotheses was by them regarded as evidence of feebleness of intellect and slavery to metaphysical prejudices. Their opinions were based upon an incomplete acquaintance with the state of physical knowledge even at that time; they were vigorously opposed in numerous papers by Boltzmann who demonstrated "the indispensability of atomistics in natural philosophy" in a most convincing manner. As we all know, the progress of experimental discovery has long since convinced the energeticians that no adequate description of material phenomena can be given without the use of atomic theories.

Boltzmann has also pointed out[5] that even the most elaborate and detailed mechanical theories of Kelvin or Maxwell, for example, are regarded by their authors themselves merely as models; that description by means of models, if accurate and convenient, is quite as legitimate as description by means of differential equations; and that the method could be thus amply justified even on the most sophisticated philosophical principles.

It may, I think, safely be said that the most remarkable example in physical science of the purely descriptive theory—the one with the least taint of the fallacy of cause and effect—is Einstein's theory of relativity. All of us who studied our Maxwell in the early nineties or previous to that time, and who have kept an interested eye upon the progress of electrodynamics in the intervening years, are aware of the great difficulties which were encountered in the attempt to extend the Maxwellian electrodynamics to moving bodies. Maxwell and Hertz both went astray in that portion of the subject. We all remember how these difficulties were slowly cleared up, step by step, especially by the masterly work of Lorentz, but with important contributions by J. J. Thomson, Heaviside, Larmor, FitzGerald, Max Abraham and others. What we now call the electron theory had its origin in this attack upon the electrodynamics of moving matter, and was not the result of any prevision that within a few years we should be able to handle, and experiment with, the disembodied electrons themselves. The final puzzle was the reconciliation of the result of the Michelson-Morley experiment with the facts of aberration, the Fresnel "coefficient of entrainment" and other optical knowledge. Most of us can remember the great perplexity which this caused; and it

[5] "Populäre Schriften," p. 1.

did not at first sight appear to be helped very much by FitzGerald's suggestion, contained in a memoir by Lodge[6] "that the cohesive force between molecules, and, therefore, the size of bodies, may be a function of their direction of motion through the ether; and accordingly that the length and breadth of Michelson's stone-supporting block were differently affected, in what happened to be, either accidentally or for some unknown reason, a compensatory manner. This seemed a rather desperate dodge; and the impression was not removed until Lorentz (who had independently made the same suggestion) showed[7] that just the right alteration of dimensions would take place if the intermolecular forces were of electrical origin. Later the experimental results of Rayleigh and of Brace forced him to the conclusion that the electron itself must be similarly contracted, and one of the consequences of his hypothesis was brilliantly verified by Bucherer.

Upon one who had followed step by step this slow and laborious, but highly interesting, course of development, with its constant action and reaction of theory and experiment upon each other, the impression of directness and simplicity made by Einstein's papers of 1905 can scarcely be exaggerated. The difficult and (at first sight) irreconcilable results of experiment, which the older theory had conscientiously "explained," were taken by Einstein as his postulates. There remained only to describe the world as it appears to an observer limited by these restrictive postulates; this proved to be (for Einstein) an apparently easy task and resulted in the Lorentz equations for bodies in motion, slightly improved, in that some relations which Lorentz had obtained only approximately were now exact. Since description and not mechanism is the essence of the method, it is unnecessary to postulate an ether; and since an observer at rest with reference to the ether would have no detectable advantage over one who was in motion, the assumption of an ether was not only useless, but actually in the way of clear description. This rejection of the ether has made Einstein's theory unpalatable to many physicists, while others (as well as many mathematicians) have been so carried away with its beauty and elegance that the use of the word ether is to them distinctly offensive. A simple rule, however, enables one to converse peaceably with either group separately; the same statements and arguments may be addressed to both, provided the word "observer" is substituted for "ether," or *vice versa*.

If we consider Einstein's theory from the pragmatic point of view we cannot fail to recognize that no new discoveries in electrodynamics have resulted from its suggestions. In this fact there appears to be support for the opinion that a theory of this type is not valuable as an instrument of research, but finds its proper place as a succinct summary of a body of knowledge after that knowledge has been acquired by other means. There are a number of considerations, however, which serve as a warning against this generalization, of which I will mention but two.

I would first call your attention to the fact that the development of thermodynamics, as based upon the two empirical laws, exemplifies a method which is very similar to that of Einstein; and we must all recognize its enormous services in the advancement of science. It has constantly served as the guide in important experimental investigations, and has predicted results which could scarcely have been foreseen on the basis of the more detailed

[6] *Phil. Trans. R. S.*, 184, p. 749 (1893).

[7] "Versuch einer Theorie," etc., § 92.

molecular and statistical theories. The converse is also true, as Boltzmann so stoutly maintained; and I think we must recognize that the progress of thermodynamics has been greatly facilitated by the interplay and mutual reaction of both types of theory.

The second example is a more direct one; it is the remarkable theory of gravitation in which the highly individual genius of Einstein has again manifested itself. It is too early to come to a definite conclusion as to its validity. It has had one striking verification in the deduction of the correct value for the unexplained motion of Mercury's perihelion; but this agreement may conceivably be due to accident and, in any case, its evidence is too slender to be regarded as establishing the theory. But we must face the distinct possibility of its ultimate success; and, in that case, we can not fail to recognize it as a brilliant triumph of the descriptive method. It is difficult to believe that any living physicist except Einstein could have constructed this theory even with the help of Minkowski's highly simplified method of description by means of four-dimensional geometry; but it is quite beyond belief that such a theory could have arisen at the present time by the use of any of the more usual methods of theoretical physics.

There is one further matter in this connection to which I should like to invite your attention. It is the question of the complete validity of Einstein's original postulate of relativity. There can be little doubt of its correctness when applied to motions of translation; speaking in terms of the ether, we may be reasonably confident that it is impossible to detect the effects of uniform translation relative to the ether. But little has been accomplished in extending the theory to motions of rotation; indeed, rotation has always been a stumbling-block to a purely relative theory of motion, as soon as dynamical considerations are introduced. As Maxwell says:[8]

> So far as regards the geometrical configuration of the earth and the heavenly bodies, it is evidently all the same
>
> "Whether the sun predominant in heaven
> Rise on the earth, or earth rise on the sun;
> He from the east his flaming road begin,
> Or she from west her silent course advance
> With inoffensive pace that spinning sleeps
> On her soft axle, while she paces even,
> And bears thee soft with the smooth air along."[9]

But, as we all know, the plane of Foucault's pendulum remains fixed with reference to the stars, and this has usually been interpreted as proving by dynamical means the absolute rotation of the earth. The thoroughgoing relativist replies, however, that the contrary supposition is equally possible; it would merely require a restatement of the principles of mechanics which happen (for some unknown reason) to take on their simplest form when referred to axes fixed with respect to the stars. The new statement of the laws of motion would seem to us very unnatural, but the essential point is not their strangeness, but that they would be *different*. To cause them to transform into themselves, as Maxwell's equations do when subjected to the Lorentz-Einstein transformation, would apparently require curious assumptions of curved space, and of time recurrent after twenty-four-hour periods, which would certainly be very foreign to the ordinary habits and preferences of the human mind, whether we assume that these habits are inherent or acquired. Even from the point of view of convenient description it seems likely that we shall do better by adhering to the belief that the stars are fixed and that the earth rotates. We must, however,

[8] "Matter and Motion," p. 154 (Van Nostrand, 1878).

[9] "Paradise Lost," Book 8, ll. 160 et seq.

admit that relativists are quite within their rights when they demand an answer to the question, "Fixed with reference to what; rotates relative to what?" Here, it seems to me, is a possible field of usefulness for the ether in addition to its original function of serving as nominative case to the verb "to undulate." This appears the more likely when we consider that the earth's magnetism has never received an explanation—or, if one chooses, a description which connects it with other physical phenomena.

I have left to the end the consideration of the most revolutionary change which the twentieth century has brought about in the outlook and methods of theoretical physics—the rapid development and great successes of the quantum hypothesis of Planck. As we have seen, the fifty years following the discovery of the conservation of energy were marked by the steady progress of dynamical theories and the conquest by them of one disputed position after another. It is true that the victory was never quite complete, that the models were always in some degree imperfect and approximate; but the success was, on the whole so great that it seemed to justify the hope that only time and labor were necessary to clear away present difficulties as so many had been overcome in the past. It had not been easy to bring thermodynamics and irreversible processes into the dynamical system, but so far as material systems were concerned, most physicists were in agreement that it had been successfully done. It is true that a violation of the second law of thermodynamics could not be shown to be impossible; but its improbability was so great that there was no reasonable expectation of its ever being observed by finite human beings. The most complete and general exposition of this great triumph of the dynamical hypothesis is contained in the "Statistical Mechanics" of Willard Gibbs, which was published in 1902, but which had been completed and given in the form of academic lectures by the author for some years previous to that date. As in all of Gibbs's work the assumptions and the results were of a very general character; but he was quite aware that at one point they were too restricted. He says:[10]

> Although our only assumption is that we are considering conservative systems of a finite number of degrees of freedom, it would seem that this is assuming far too much, so far as the bodies of nature are concerned. The phenomena of radiant heat, which certainly should not be neglected in any complete system of thermodynamics, and the electrical phenomena associated with the combination of atoms, seem to show that the hypothesis of systems of a finite number of degrees of freedom is inadequate for the explanation of the properties of bodies.

The difficulties involved in the possession by the continuous ether of an infinite number of degrees of freedom were brought more clearly to light in 1900 by Lord Rayleigh's formula for black body radiation. It was quite irreconcilable with the measurements of Paschen and, moreover, it led to a kind of superdissipation of energy into high frequency vibrations of the ether which appeared entirely out of accord with the facts of empirical thermodynamics. Paschen's observations were well represented by the formula which had been obtained by Wien, who assumed the Maxwellian distribution of velocities among the molecules of the black radiator, and also that the wave-length radiated by any molecule was a function of its velocity. Later experiments by Lummer and Pringsheim and by Rubens and Kurlbaum, with longer wave-lengths and higher temperatures, approximated to the Rayleigh formula.

[10] "Statistical Mechanics," p. 167.

Planck endeavored to find a mathematical compromise which should reduce to Wien's formula when λT was small and to that of Rayleigh when λT was great. In this way[11] he was led to the celebrated formula which has proved to be of such unexpected importance in the development of theoretical physics. In its original publication, however, the formula was otherwise deduced.[12] Planck had previously calculated the entropy of a system of linear resonators and believed that he had proved Wien's formula to be a necessary consequence of the second law.[13] To obtain the new formula (by a process similar to that of Boltzmann in the kinetic theory of gases), he found it necessary to assume that energy was absorbed and radiated discontinuously. To satisfy Wien's displacement law these discrete energy quanta must be proportional to the frequency of the radiation, and thus the constant, h, came into existence.

The process was not very convincing and I suppose that, if nothing else had come of it, Planck's result would have been regarded as an empirical formula for which a satisfactory theoretical basis was lacking. But there were other puzzles which were, at nearly the same time, troubling the minds of physicists. One was the curious relation between X-rays of a certain hardness and the speed of the secondary electrons which they caused to be emitted from a metal. We all remember how Bragg was led by these difficulties to support a corpuscular theory of X-rays. The same difficulties existed in the case of photo-electrons and the ultra-violet light which liberated them. Einstein also proposed a quasi-corpuscular theory in which, however, instead of actual corpuscles, he substituted light-quanta whose energy was equal to Planck's $h\nu$. It was not difficult to show, as Lorentz did, that Einstein's quanta were quite irreconcilable with the phenomena of diffraction; but the fact remains that the quantitative predictions of his theory have been verified in the case of both X-rays and light, in the latter instance with great accuracy by Professor Millikan and his pupils.

Time permits only the barest mention of Debye's daring application of Planck's formula to the elastic vibrations of solid bodies, his calculations of their specific heats upon this basis, and the remarkable agreement of the calculated values with the experimental results of Nernst and his collaborators. I must be equally brief in referring to Bohr's theory of line spectra in which the *form* of the Balmer progression is undoubtedly introduced in the assumptions; but the numerical value of Rydberg's constant is accurately calculated from the mass and charge of the electron and the inevitable h. In all these applications the same characteristics are observable: the fundamental ideas are not clear and precise, except arithmetically; if we try to make them so, we encounter apparently insuperable contradictions with some of the most firmly established experimental facts; the deductions from the premises do not follow inevitably, but must be helped out by special hypotheses in each different application; but numerical relations of surprising exactness are obtained, and an account is given of whole classes of phenomena which seem to be quite beyond the scope of the "classical" methods of twenty years ago. We do not know whether Planck's constant is an atom of Hamiltonian action, or of angular momentum, or of something quite different from either; but we can not doubt that it is a physical constant comparable in importance with the

[11] Planck, "Wärmestrahlung," 1te Aufl., p. 219.
[12] Planck, *Ann. d. Phys.*, 4, p. 553 (1901).
[13] *Ann. d. Phys.*, 1, p. 118 (1900).

velocity of light and the electronic charge.

Poincaré's demonstration of the necessity for discontinuities in atomic processes if the total black radiation is to remain finite has not yet been successfully questioned. If it stands, we must not only give up the hope of bringing the phenomena of physics under the sway of generalized dynamics—we must renounce even the humbler ambition of describing them, in all their details, by means of differential equations. It will certainly be a triumph of the atomistic method—though unexpected and somewhat embarrassing to its most ardent supporters—if our very mathematics must become atomic.

The present state of theoretical physics is obviously one of transition, with all the discomfort that such a state involves. We are waiting for a synthesis of elements which are apparently discordant and mutually contradictory. The experience of the past forbids us to doubt that the necessary reconciliation will come in time; and we can foresee that it will be comparable with the greatest generalizations in the history of science. It may be that we must await the appearance of another Newton; or it may be that the result will be achieved in a more democratic manner by the cooperation of many lesser men.

H. A. Bumstead
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CYRILLE GRAND'EURY

The writer has waited some months in the hope that some one whose acquaintance was not limited to an occasional interchange of letters might publish a note of appreciation of the life and work of this savant—the last of the illustrious trio of paleobotanist, Renault, Zeiller, Grand'Eury—who made the French Carboniferous and Permian floras classic and a standard for the whole world.

François Cyrille Grand'Eury was born at Houdreville (Meurthe) on March 9, 1839. He was a mining engineer by profession and early in his career he became interested in the fossil plants of the Carboniferous, publishing a paper on the St. Étienne flora as early as 1869. His large work on the Loire flora, a folio monograph of 624 pages and 27 plates, was published as a memoir of the French Academy in 1877 and is one of the most comprehensive works of its kind ever printed. The only other large systematic work from his pen was that on the geology and paleontology of the coalfield of the Gard published in 1890.

Grand'Eury was always much interested in the stratigraphic applications of his subject, in the conditions of growth of the coal plants, and the origin of coal—subjects upon which he repeatedly published. He may be said to have established the chronologic succession of floras for the coal seams of the Stephanian, named from the typical development of this stage at St. Étienne. Probably no other student of Carboniferous floras had so thorough a field experience or saw one tenth the amount of material in place in the rocks as did Grand'Eury. Consequently his observations on the habit, sizes and positions of growth of the various Cordaites, Lepidophytes and Calamites are especially trustworthy. His name is inseparably associated with the elucidation of the habit and morphology of Cordaites and his restorations of these and other coal plants are to be found in every text-book.

He published a memoir upon the formation of coal in the *Annales des Mines* in 1882, a subject to which he returned in his paper before the International Geological Congress in 1901, and in his last large work commenced in 1912. He was not a voluminous writer and with the exception of his work on the Carboniferous plants of the Spanish peninsula, embodied in lists of species, all of his work was centered on the French floras. Nor did he, so far as I know, publish anything in the fields of Mesozoic and Cenozoic paleobotany, unless his paper of 1902 on the formation of stipite, brown coal and lignite can be so considered.

He did, however, contribute a very large

number of short papers to the *Comptes rendus* of the French Academy, among which those later ones relating to the habits and seed-like fructifications in *Callipteris, Neuropteris, Pecopteris* and *Sphenopteris* are especially noteworthy. His last great work, commenced in 1912 with the collaboration of his son, one showing where his chief interest centered, was entitled "Recherches géobotaniques sur les Forêts et Sols fossiles et sur la végétation et la Flore Houillères." Influenced by his experience in the fresh-water basins of central France, he was an advocate, albeit an impartial one, of the allochthonous origin of coal beds.

He was elected to the Société Géologique in 1877 and hence was one of the oldest surviving members at the time of his death. He was elected a correspondent of the Institute in botany in the spring of 1885. Throughout a reasonably long life he was actively engaged in mining work and was long a resident of St. Étienne, where he was an honorary professor in the School of Mines. A few years ago he removed to Malzéville, a suburb of Nancy, where he died on July 22, his death undoubtedly hastened by the untimely fate of his son on the field of battle.

In Grand'Eury science has lost another admirable representative of the French school. Of a kindly disposition, generous and courteous in all his intercourse, well informed in all he wrote, he will be sadly missed among the depleted ranks of paleobotanists among whom he labored for over half a century. With the sorrow of Zeiller's death still heavy, we have now to lay wreaths on the tombs of memory for Grand'Eury, and for his recently departed colleagues—Lignier, of Caen, and Bertrand, of Lille—would that Cuvier were still alive to fittingly pronounce their éloges.

E. W. B.

SCIENTIFIC EVENTS

ORNITHOLOGICAL FIELD WORK IN 1917

It is stated in the *Auk* that, while war conditions have necessarily curtailed activity in various directions and especially in field work, the museums have sent out expeditions and special collectors.

The Museum of Vertebrate Zoology of Berkeley devoted its attention chiefly to the southwest. H. S. Swarth visited southern Arizona and obtained material for a report on the birds found on the Apache Trail, while Grinnell and Dixon spent some time in the Death Valley region in California. In the north W. E. C. Todd was in the field five months in charge of the Carnegie Museum Expedition to northern Quebec. In tropical America the activity of previous years has decreased with the return of the American Museum Expeditions from South America but one party, comprising Messrs. Miller, Griscom and Richardson, spent four months collecting for the Museum in Nicarauga. In the West Indies, Haiti and San Domingo have been the center of attraction. W. L. Abbott, Rollo H. Beck, and Paul Bartsch visited the islands at different times and each secured some remarkable birds or made substantial additions to our knowledge of the local avifauna. In South America Beebe spent some time at the tropical laboratory near Georgetown, British Guiana, and Beck returned from southern Patagonia with rich collections of sea birds. From the Orient the American Museum Expedition to China, Yunnan, and northern India in charge of Roy C. Andrews returned after successfully completing its field work, and from Celebes, H. C. Raven sent some valuable collections of birds to the U. S. National Museum.

In the United States the work of the Biological Survey has been carried on with the usual activity in a number of states. In the south A. H. Howell continued his field studies of the birds of Alabama and Francis Harper visited the Okefinokee Swamp in Georgia and the everglade region in Florida. In the west H. H. T. Jackson began work on a biological survey of Wisconsin and H. C. Oberholser investigated the breeding ground of waterfowl in North Dakota. In Montana E. A. Preble collected in the southeastern part of the state south of the Northern Pacific Railroad, and Mr. and Mrs. Vernon Bailey spent some weeks studying the birds of the Glacier National

Park and collected material for a report to be issued in cooperation with the National Park Service. In the Northwest preliminary work on a biological survey of Washington was begun by W. P. Taylor and in the southwest E. A. Goldman collected in northern Arizona south of the Grand Canyon.

THE ANNUAL MEETING OF THE NEW YORK ZOOLOGICAL SOCIETY

The New York Zoological Society held its annual meeting on the evening of January 8 at the Waldorf-Astoria Hotel. When Professor Henry Fairfield Osborn, president of the society, called the meeting to order, there were more than a thousand members and their friends present.

In his annual report Madison Grant, chairman of the executive committee, said that the attendance at the New York Zoological Park and at the aquarium showed a substantial increase over 1916. The attendance at the park during 1917 was 1,898,414, and that of the aquarium 1,595,118, making a total attendance of 3,493,532. The cost per visit was about 7 cents for these two institutions during the past year. The number of exhibits at the park is about the same as last year, although there has been a slight increase in the number of species. There are over 4,000 animals at the park at the present time. The collection at the aquarium shows a slight increase over last year, and there are now more than 6,000 living specimens on exhibitions.

In his report, Dr. Charles H. Townsend, director of the aquarium, said that present conditions were almost intolerable because sea water invaded the engine-room and passed throughout the basement of the entire building through the pipe galleries. The result was that the building was unsanitary. Application would be made to the city, Dr. Townsend said, for an appropriation of $100,000 to remove the boilers and engines to the front of the building beyond the reach of sea water. One of the advantages of this alteration, he pointed out, would be increased exhibition space and more room for office work.

Dr. William T. Hornaday, director of the Zoological Park, after making his report, called attention to the need of Congress ratifying the arrangement between the United States and Canada for the protection of migratory birds. Dr. Hornaday said that Canada had already accepted the proposal and diligently and forcefully carried it into effect, despite the distraction of her participation in a great war. The arrangement, he said, had been held up in the Foreign Relations Committee of the House of Representatives, and he urged that action be taken at once. He declared that our food supply depended to a large extent on the enactment of this bill, as the migratory birds feed on crop-destroying insects. A resolution which he offered urging the President and Congress to take immediate action was unanimously adopted by the meeting. Two series of pictures, one a motion picture taken in the Marine Biological Laboratory at Naples, Italy, by Dr. Edward Bosio, and the other a series of natural-color pictures taken by Mrs. Roy C. Andrews in the Chinese province of Yunnan, were shown for the first time. Pictures taken by Donald B. MacMillan on the recent Crocker Land Expedition sent out by the American Museum of Natural History and the American Geographical Society were also shown, as well as motion pictures taken in the New York Zoological Park by Raymond L. Ditmars.

WARTIME SERVICE OF THE UNIVERSITY OF CALIFORNIA

According to the report presented by President Benjamin Ide Wheeler to the regents of the University of California at their December meeting, nearly three thousand students, alumni, former students and members of the faculty of the University of California are now in military or naval service. The University of California has organized and has been conducting since May 21 a school of military aeronautics, in which some five hundred flying cadets are now being trained in an eight-weeks course. A new contingent is admitted each week. The university is now teaching forty-five men in a school of navigation, conducted in conjunction with the U. S. Shipping Board, for the training of officers for the merchant marine. For the third time, a six-weeks' course is about to be begun for the

training of chief storekeepers for the Ordnance Department of the U. S. Army.

The undergraduate men remaining at Berkeley are organized as a unit of the Reserve Officers Training Corps. A course in naval engineering will be inaugurated in January, which by one year of special training will qualify men for examination as ensigns in the Navy. Courses in naval architecture and military engineering are also to be offered. An institute for home service has been conducted at the request of the Red Cross, for the training of home-service relief workers. A military information office maintained by the university in the office of the alumni secretary has advised thousands of men as to how to find opportunity to serve the nation in its war-time emergency where their special training will be of most service.

The department of agriculture has turned practically its whole activity toward speeding up the production of food in California, with notable results. Special researches are being carried on at the request of the National and the State Councils of Defense by experts in the fields of agriculture, astronomy, botany, chemistry, economics, engineering, geology, medicine, psychology, zoology, etc.

Between April 6 and October 31, 1917, the University of California expended or administered for specific war purposes a total of one hundred and sixty-one thousand dollars.

The University of California Medical School has sent into service Hospital Unit No. 30, under Major E. S. Kilgore, with twenty-three members of the faculty of the medical school among its officers. The medical school has conducted thousands of examinations for military or naval service, and many other examinations for the California State Board of Health, in connection with the selective draft.

Dr. T. Brailsford Robertson, professor of biochemistry, has isolated the new growth-controlling substance, "Tethelin," and has given his patents to the university for the endowment of medical research. This new substance promises to be of great value in causing the rapid healing of wounds or fractured bones which had previously refused to yield to treatment.

The staff of the Hooper Foundation for Medical Research are obtaining valuable results in investigations concerning anemia, shock, typhoid carriers, and other problems of war-time significance.

The University of California Dental School is giving free dental care to men who through defects of the teeth would otherwise be disqualified under the selective draft, and a large number of its faculty and alumni have become officers in the Dental Service of the Army.

The diversity of tasks which individual members of the faculty of the University of California are carrying on as war-time emergencies may be illustrated by brief mention of some of the activities in which some of the members of the faculty are engaged:

President Benjamin Ide Wheeler is chairman of the Committee on Resources and Food Supply of the California State Council of Defense, represented Governor Stephens at the conference of the states, and has been active in varied fields of war-time work. David P. Barrows, professor of political science, has been commissioned as a major and has gone to the Philippines, where his eight years of experience as director of education and as chief of the Bureau of Non-Christian Tribes will be of special value in military intelligence work. Dean Herbert C. Moffitt, of the medical school, is a major in the Army Medical Service and at the head of a hospital at a training camp, and so in charge of the health of some thirty thousand men. Comptroller Ralph P. Merritt is federal food commissioner for California. Gilbert N. Lewis, dean of the college of chemistry, has been commissioned as a major in the Ordnance Corps and has been sent to France for gas work. Dr. William Palmer Lucas, professor of pediatrics in the University of California Medical School, is in France, in charge of the Children's Bureau of the Red Cross for France and Serbia. Professor W. B. Herms, of the department of agriculture, has been making an entomological survey of sanitary conditions in the neighborhood of the cantonments of the western depart-

ment of the Army, to aid in preventing the spread of those diseases, such as malaria, which are carried by insects. Professors H. M. Hall and T. H. Goodspeed, of the department of botany, have been investigating certain native plants of California which can be used as a source of rubber in case of national necessity. Practically all of the members of the department of chemistry are engaged in confidential researches as to chemical problems the national authorities have asked them to take up. Professor Stuart Daggett, of the department of economics, has reported on the supply of iron and steel on the Pacific coast and Professor Henry R. Hatfield, of the department of economics, dean of the college of commerce, has reported on the relation of the state banks to the Federal Reserve System. Professor F. E. Pernot, of the department of electrical engineering, is in Washington aiding with various war-time electrical problems. Professor Charles Gilman Hyde, of the chair of sanitary engineering, designed fifteen miles of sewer system for Camp Fremont. Professor C. C. Wiskocil and his colleagues in the civil engineering department have made tests of airplane fastenings and woods to be used in the construction of airplanes. Professor C. L. Cory, dean of the college of mechanics, has investigated problems in the fixation of nitrogen from the air by direct electric arc furnace process. Professor B. M. Woods, of the deparment of mechanics, as president of the Academic Board of the School of Military Aeronautics, is directing the instruction given to the flying cadets. Professor George D. Louderback, of the department of geology, has reported on sources for a supply of manganese ores. Professor George M. Stratton, as a captain in the Signal Corps, is enlisting officer in San Francisco for the Aviation Service, and he and Professor Warner Brown, of the department of psychology, have developed tests to determine the fitness of young men to become military aviators. Professor William E. Ritter, director of the Scripps Institution for Biological Research, has investigated the supply of food fishes in the Pacific Ocean not as yet used by the fishermen and the canneries. Professor C. A. Kofoid and Professor W. W. Cort, of the department of zoology, have investigated the hookworm, and organisms responsible for trench dysentery. Professor Lincoln Hutchinson, of the department of commerce, is in Washington as tin expert of the War Trade Board. Professor Joel H. Hildebrand has gone to Washington to become a captain in the Ordnance Department and to aid in coordinating the war-time researches of chemists throughout the country. George E. Dickie, of the department of military science and tactics, is the Pacific coast representative of the War Department and Navy Department Commissions on Training Camp activities. Professor H. B. Langille, of the department of mechanics, is an inspector of naval construction for the government, at the Union Iron Works.

SCIENTIFIC NOTES AND NEWS

M. Painlevé has been elected president of the Paris Academy of Sciences, succeeding M. d'Arsonval. M. Léon Guignard, professor of botany at the School of Pharmacy of Paris, has been elected vice-president.

The Nichols Medal for meritorious research in organic chemistry has been conferred on Professor Treat B. Johnson, of the Sheffield Scientific School of Yale University. The medal is awarded annually by the New York Section of the American Chemical Society on the merit of the original communications published in the journal of the society.

At the last meeting of the New York Section of the Society of Chemical Industry, the Perkin Medal was presented to Auguste J. Rossi, by Dr. William H. Nichols, past-president of the society, and Dr. F. A. J. Fitzgerald gave an account of Dr. Rossi and his work.

Dr. C. Gordon Hewitt, F.R.S.C., dominion entomologist and consulting zoologist, of the Department of Agriculture, Ottawa, has been awarded the gold medal of the Royal Society of Canada for the Protection of Birds, and has been elected an honorary fellow of the society, in recognition of his services to the cause of bird protection in England and in Canada,

and particularly in connection with the treaty between Canada and the United States for the protection of migratory birds.

PROFESSOR GEORGE GRANT MACCURDY, of Yale University, has been made a member of the Committee on Anthropology of the National Research Council.

PROFESSOR ROSWELL H. JOHNSON, of the University of Pittsburgh, and Professor Frederick Ehrenfeld, of the University of Pennsylvania, have been appointed by Governor Brumbaugh as commissioners of the Topographic and Geologic Survey Commission of Pennsylvania. Senator G. W. McNees holds over as the third member.

MR. PAUL M. REA has resigned the secretaryship of the American Association of Museums after eleven and a half years of service. Mr. Rea has been appointed vice-director of War Savings for South Carolina. The council has filled the vacancy for the remainder of the year by the appointment of Harold L. Madison, curator of the Park Museum, Providence, R. I.

MR. SCHACHNE ISAACS, instructor in psychology, University of Cincinnati, has been commissioned first lieutenant, Sanitary Corps, National Army. Lieutenant Isaacs is associated with Captain Knight Dunlap on the psychological research in high altitude aviation. He has been assigned to the Mineola, L. I., aviation camp where a laboratory is in process of construction.

GEORGE K. K. LINK, professor of plant physiology in the University of Nebraska, has been granted a leave of absence to undertake war emergency work in the Bureau of Plant Industry. He is engaged as pathologist in the market distribution and food survey work of the Department of Agriculture and is instructing the inspectors of the newly created inspection service in the detection of diseases of vegetable crops. This inspection service has been opened by the Bureau of Markets and covers the principal markets of the country. The Navy and Army, in purchasing vegetables for the fleet, for overseas supply ships and transports and the Quartermaster's depots, are making use of this service. Dr. Link is also investigating the occurrence of diseases of perishable vegetables in the terminal markets of the United States.

DR. HERBERT E. IVES, physicist of the United Gas Improvement Company, Philadelphia, Pa., lectured before the Franklin Institute of Philadelphia on January 10 on "The physics of the Welsbach mantle," and Professor W. P. Mason, of the Rensselaer Polytechnic Institute, lectured on January 16 on "Camp sanitation."

PROFESSOR CHARLES E. PELLEW is giving a course of four lectures, on Saturday evenings at 8 P.M., at the Metropolitan Museum of Art, upon "The dyestuffs of the ancients."

DR. LAWRENCE J. HENDERSON, professor of biological chemistry in Harvard University, will give a series of lectures on food conservation at Smith College. The lectures will be open to the public.

A SERIES of five lectures in the Herter Foundation were delivered from January 7 to 11, at the Carnegie Laboratory of the University and Bellevue Hospital Medical College, by Major Edward K. Dunham, M. R. C., U. S. Army, emeritus professor of pathology, on "Principles underlying the treatment of infected wounds."

A MEETING of the Faraday Society was held on January 14 in the rooms of the Royal Society of Arts, when a general discussion on the setting of cements and plasters was opened by Dr. C. H. Desch.

THE Ramsay Memorial Fund, which was instituted a year ago with the object of raising a sum of £100,000 as a suitable memorial to the late Professor Sir William Ramsay, has now reached a sum of just above £30,000. The latest and most important donation to the fund has been been a sum of £5,000, contributed by Mrs. Wharrie.

DR. A. H. PURDUE, state geologist of Tennessee, died as a result of an operation, on December 12, aged fifty-six years.

JOSEPH PRICE REMINGTON, since 1893 dean of the Philadelphia College of Pharmacy and a member of the revision committee of the United States Pharmacopœia since 1880 and

its chairman since 1901, died in Philadelphia on January 1, aged seventy years.

The death is announced of Professor G. P. Girdwood, professor of chemistry in McGill University. He was born in London in 1832 and took up medical practise in Montreal in 1864. From 1872 to 1902, he was professor of chemistry in the faculty of medicine.

W. J. E. Foakes, late chief government inspector of Explosives for Cape Colony, has died in London.

Tuberculosis and war were discussed at a national conference of experts in connection with the annual meeting of the board of directors of the National Jewish Hospital for Consumptives at the Hotel Savoy, New York, on January 13. Addresses were made by Jane Addams, of Hull House, Chicago; Dr. Herman M. Biggs, state commissioner of health; Colonel G. E. Bushnell, of the Surgeon-General's Department; Colonel D. U. Dercle, representing the Medical Department of the French Government; Dr. John H. Finley, commissioner of education of the State of New York, and Dr. Charles J. Hatfield, executive secretary of the National Association for the Study and Prevention of Tuberculosis.

A Ministry of Public Health and Social Welfare has been constituted for Austria with Dr. Baernreither as the first minister. It is to supervise the care of war invalids, to combat war diseases, and to centralize pre-existing, uncoordinated departments of public health and sociology. It is to have the care also of the dependents of fallen soldiers, infant welfare, housing and insurance.

In consequence of strong protests, the British War Cabinet will reconsider its proposal to take over the British Museum for the use of the Air Board. According to cablegrams to the press the *Times* prints an editorial and also many letters against the proposal. Other newspapers also raise a vigorour outcry against the appropriation of the museum, declaring it "preposterous," "a serious scandal," and an "unjustifiable act of vandalism." The *Manchester Guardian* says that the suggestion to take over the building is an incredible outrage, which should never be suffered while there remains a hotel, a private mansion, or, if need be, a royal palace that can be commandeered. Sir John E. Sandys, public orator in Cambridge University, has written a vigorous letter of protest. He pointed out that it would be impossible to remove more than a fraction of the valuable contents of the museum and that what was left probably would be damaged by ill-usage. Sir John also referred to the fire risk of the new occupancy, and, moreover, that the building, whose treasures are the envy of Germany, had not as yet been attacked from the air. He feared, however, that when the air board was installed there it would be regarded as the legitimate object of an enemy attack.

The reappearance of Encke's comet was reported on January 4 in a dispatch to the Harvard College Observatory from Copenhagen. The position was given as follows: Right ascension, 22 hours 59 minues 49 seconds; declination, north 3 degrees 17 minutes 35 seconds. The comet was observed by Professor Schorr of the Bergedorf Observatory on the evening of December 30.

The late G. F. Melville, an Edinburgh advocate, has made a bequest of about £250,000, the income of which is to be used ultimately for the care and cure of cancer under a special trust which he has established.

After the adjournment of the meeting of the Geological Society of America held in St. Louis, December 27 to 29, an excursion was conducted to the southeastern Missouri Lead District, under the direction of Professor W. A. Tarr, of the University of Missouri. The occurrences of the lead ore at Flat River were first studied, the party spending considerable time underground investigating the workings of the Federal Lead Company. Mine La Motte and the North American Mine in the vicinity of Fredericton were also visited. The party included Professors R. M. Bagg (Lawrence College), A. P. Coleman (University of Toronto), C. W. Knight (assistant provincial geologist of Ontario), E. H. Kraus (University of Michigan), T. R. Van Horn (Case School of Science), L. G. Westgate

(Wesleyan University), and W. A. Tarr (University of Missouri).

FEDERAL food administrators from thirty-eight states and from the District of Columbia and Hawaii and representatives from all the other states met in Washington on January 9 for a two-days' conference. Seventy-six delegates were at the meeting. They were addressed at the opening by Herbert Hoover, United States Food Administrator; by the Hon. David F. Houston, Secretary of Agriculture, and by several of Mr. Hoover's assistants. The administrators come to Washington every few months for conferences with members of the Food Administration, in order that a closer touch between the states may be established and to give each of them a clear understanding of the problems and conditions that must be met. The administrators were entertained at luncheon in the Food Administration Building and attended an informal dinner at the New Willard Hotel. Both the luncheon and dinner were in strict accordance with food-conservation rules. The following administrators were in attendance: Professor Alfred Atkinson, Montana; Edwin G. Baetjer, Maryland; Dr. Harry E. Barnard, Indiana; Braxton Beacham, Florida; Dr. Stratton D. Brooks, Oklahoma; J. F. Child, Hawaii; Alfred M. Coats, Rhode Island; Fred C. Croxton, Ohio; J. F. Deems, Iowa; Theodore C. Diers, Wyoming; William Elliott, South Carolina; Ralph C. Ely, New Mexico; P. M. Harding, Mississippi; James Hartness, Vermont; Charles Hebbard, Washington; Howard Heinz, Pennsylvania; Charles N. Herreid, South Dakota; Richard M. Hobbie, Alabama; Walter P. Innis, Kansas; Dr. Leon S. Merrill, Maine; Ralph P. Merritt, California; Charles E. Treman, New York state; Edmund Mitchell, Delaware; H. A. Morgan, Tennessee; Frederick B. Mumford, Missouri; Earl W. Oblebay, West Virginia; Henry A. Page, North Carolina; John M. Parker, Louisiana; E. A. Peden, Texas; George A. Prescott, Michigan; Fred M. Sackett, Kentucky; Robert Scoville, Connecticut; Dr. Andrew M. Soule, Georgia; Huntley N. Spaulding, New Hampshire; Gurden W. Wattles, Nebraska; Harry A. Wheeler, Illinois; Col. E. B. White, Virginia; Arthur Williams, New York City, and Clarence R. Wilson, District of Columbia.

THE *American Medical Journal* reports that the large collection of birds and mammals obtained as a result of the American Museum's Asiatic Zoological Expedition to China, conducted by Mr. Roy C. Andrews, has been placed on display just as it was received instead of first putting it through the processes of preparation. This collection comprises hundreds of skins of beautiful tropical birds, including newly discovered pheasants and peacocks. Small bright-hued jungle fowls are interesting as the ancestors of the present barnyard fowl which is playing such an important part in the food problem at the present time. For thousands of years this original type has existed in the heart of China. Unusual rodent forms are represented in the black flying squirrels, four feet long, together with huge rats, including the rare bamboo rat, scores of mice of strange appearance and odd variations of the mole. The chipmunks include several varieties hitherto undescribed by zoologists. Skins of serows and gorals, strange animals intermediate between the goat and the sheep, are also included in the exhibit.

UNIVERSITY AND EDUCATIONAL NEWS

AT New York University Hazen G. Tyler has been appointed professor of mechanical engineering; Dr. Edward K. Dunham, emeritus professor of pathology, has been appointed Herter lecturer, and Dr. John Charles McCoy has been appointed clinical professor of surgery. Dean Samuel A. Brown has been promoted from assistant professor of medicine to professor of therapeutics; Dr. Willis C. Noble, from lecturer on bacteriology to assistant professor of hygiene, and Dr. James F. Nagle, from instructor in medicine to clinical professor of medicine.

DR. L. C. GLENN, who was on leave of absence from Vanderbilt University last year in

the employ of the Sinclair Oil and Refining Corporation as geologist, has returned to the university this year, but retains his connection with the Sinclair companies.

Mr. L. A. Rumsey, former instructor in organic chemistry at Iowa State College, has been appointed head of the department of chemistry at Denison University, Granville, Ohio.

Dr. R. K. Strong, of the University of Chicago, has been appointed as professor of industrial chemistry at the Oregon Agricultural College.

DISCUSSION AND CORRESPONDENCE

RHYTHMIC PRECIPITATION

The abstract of Dr. H. N. Holmes's paper, read before the Kansas City meeting of the American Chemical Society, April 12, 1917, which appears in Science, November 2, 1917, calls for some discussion. He proposes a "new" theory to account for rhythmic precipitation bands. I have recently given a short account of some of the earlier work in the subject in a paper in the *American Journal of Science* for January, 1917, from which it is clear that the theory is comparatively old, having been suggested twenty years ago by Ostwald senior, and established six years later by Morse and Pierce.[1] Later workers have agreed with these pioneers, and recently I have shown that the rates of diffusion of the reagents have to be taken into account in explaining rhythmic precipitation, and that under certain conditions bands which become successively closer, or equally spaced bands, may be produced. Morse and Pierce also showed, fourteen years ago, that a gel is not essential to the formation of precipitates in separated bands, having obtained them in aqueous solutions. It is of interest and importance that Dr. Holmes has obtained them in loosely packed flowers of sulphur.

It might be asked what Dr. Holmes means by "crystalline banding of mercuric iodide." Is it possible that "banding of crystalline mercuric iodide" is meant? Again, it is difficult to understand what is meant by "a thickness of a few cubic centimeters," thickness usually being measured in one dimension, not in three dimensions.

I would take exception to the statement: "The color arrangement of agate is an excellent example of the phenomenon." It may possibly be an example of the phenomenon. I have not studied agates in sufficient detail to discuss the subject at this time, but such cursory examinations of agates as I have made have been sufficient to indicate that the offhand acceptation of agates as examples of rhythmic banding by precipitation within a medium of gelatinous silica is inadvisable. There are very few agates which are not susceptible of other explanation. Liesegang, in his "Geologische Diffusionen," after discussing agates as products of rhythmic precipitation within gelatinous silica, is careful to point out that he does not propose to apply this explanation universally.

It is unnecessary to state that the description of Dr. Holmes's experiments with silicic acid gels will be awaited with interest. From the partial account given in his abstract the experiments would appear to be along similar lines to those of Hatschek, and Hatschek and Simon.

J. Stansfield

Geological Department,
McGill University

[1] Morse, H. W., and Pierce, G. W., *Zeitschr. phys. chem.*, Vol. XLV., 1903, p. 589, or *Physical Review*, Vol. XVII., No. 3, September, 1903, p. 129.

GRAVITATIONAL REPULSION AND THE COMET

The results presented by the writer in a paper recently published by the Academy of Science of St. Louis[1] may be of assistance in explaining the behavior of the comæ and tails of comets. Twenty years ago Newcomb gave the following description in Johnson's Universal Cyclopædia.

> When a bright comet is carefully examined with a powerful telescope, a bow will sometimes be seen, partially bent around the nucleus on the side towards the sun. If watched from night to night, this bow will be found to expand from the nucleus, become diffused and finally lose itself in the nebulosity of the coma. . . . These bows seem to be

[1] *Trans.*, Vol. XXVIII., No. 5, November 8, 1917.

formed of hemispherical envelopes of vapor, which rise from the nucleus itself, dissolve themselves in the coma, and are gradually repelled from the sun so as to form the material of the tail.

The turning point in the motion of these dust particles which are repelled towards the sun may be thus defined. The gravitational repulsion of the nucleus, the gravitational attraction (or repulsion) of the sun, and the repulsion due to the pressure of light-waves, are balanced against each other. These dust particles are gradually dispersed into space. The radiation of negative corpuscles from the sun, superposed upon the other causes above mentioned, seems to furnish a full explanation of the phenomena of the comet.

FRANCIS E. NIPHER

BARITE IN GEORGIA

IN the Friday, December 21, 1917, issue of SCIENCE, on page 611, under the title of "Chemical industries of the United States," you quote from the annual report of Franklin K. Lane, Secretary of the Interior,

> Before the war 40,000 tons of barite were imported from Germany for the manufacture of lithopone. Now five companies are producing this article from deposits in Tennessee, Kentucky, Virginia and Missouri.

This quotation is incorrect in that over 50 per cent. of the barite produced in the United States comes from deposits near Cartersville, Georgia. There are three companies in the Cartersville district that have produced over 20,000 tons apiece during 1917, while the total output from this dictrict could be conservatively estimated at 75,000 tons during 1917. You do not mention that any barite at all is mined in Georgia, and I feel that this should be brought to the attention of the public, as it is an injustice to this mining district, as they are the largest producers of this mineral in the United States.

WILBUR A. NELSON

CARTERSVILLE, GA.

MANGANESE IN ALBERTA

MY attention has been directed to an article in SCIENCE, January 4, 1918, page 20, describing a large deposit of manganese occurring in the Cypress Hills, Alberta. Permit me to say, through the medium of your valuable magazine, that the Geological Survey has no information regarding a deposit of the nature described. During the summer of 1917 an examination was made by a member of the staff of the Geological Survey of a deposit of low-grade manganese in the Cypress Hills about 55 miles from Maple Creek and 15 miles from Govenlock station on the Canadian Pacific railway. Three samples gave on analysis 8.24, 18.45 and 17.59 per cent. of managanse. A shipment of 500 pounds of the material was tested in the Ore Dressing and Metallurgical Laboratories of the Mines Branch and the conclusion was reached that it is of too low a grade to be worked economically under present conditions.

WILLIAM MCINNES,
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SCIENTIFIC BOOKS

Studies on the Variation, Distribution, and Evolution of the Genus Partula. The Species Inhabiting Tahiti. By H. E. CRAMPTON. *Carnegie Institution of Washington.* 1916.

This work has an interest for the student of evolution in any group, quite apart from its special interest to the conchologist. Such variable non-mobile land shells scattered widely among oceanic islands offer a field in many aspects most favorable for compilation of statistics bearing on speciation. Also, a very large series of material has been studied and adequately described and figured.

Evolutionary writers frequently attempt to balance an imposing structure of hypothesis on a few inadequate facts. The paper under discussion seems to have gone to the other extreme in laying the *Partula* variation almost entirely to the innate tendency to vary. The statement that "the originative influence of the 'environment' seems to be little or nothing" (p. 12) is perhaps justifiable, but that "isolation proves to be a 'condition' and not a 'factor' in differentiation of forms belonging to this genus" is weakened when we

read that "with only one exception, each group of islands has its own characteristic species which occur nowhere else.

"The same correlation between geographical and specific discontinuity is displayed by the species of the different islands of one and the same group for each member possesses distinct species not found in the others" (p. 11); and that the various varieties are confined within rather easily definable geographic limits.

It would seem that the isolation factor had been so taken for granted as to be overlooked. It has certainly not been the only, perhaps not a necessary, factor. For instance (p. 309), we find mention of "two absolutely independent varieties [of *P. otaheitana*], *rubescens* and *affinis*, which have almost identical geographical limits; yet they stand in the sharpest possible contrast to one another." A very intensive study of these two varieties would, in the reviewer's opinion, almost surely show some slight difference of habit, of adaptation to the same environment, otherwise being too far separate to interbreed freely, one of them should have crowded the other out.

Perhaps, the conclusion of the widest interest, if not of the greatest importance, is found in the following statement. "The evidence tends to prove that the dominant geological process in South Pacific regions has been one of subsidence, which has progressively isolated various mountain ranges previously connected, so that they have become separate island-masses, which, in their turn, have been subsequently converted into the disconnected islands of the several groups."

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SPECIAL ARTICLES

FURTHER EVIDENCE RELATIVE TO THE VARIETAL RESISTANCE OF PEANUTS TO SCLEROTIUM ROLFSII

During 1916 data were collected[1] which indicated that there is a marked difference in the susceptibility of peanut varieties to the attacks of *Sclerotium Rolfsii.*

The soil in the plots where the peanut rotation experiment is being conducted has been proven to be thoroughly infested with *Sclerotium Rolfsii,* and the Valencia variety has shown great susceptibility to the attacks of this fungus; therefore, at the writer's suggestion, the use of the Valencia variety for the rotation experiment was discontinued, and commercial seed of the Virginia Bunch variety was substituted for use in 1917. Plots one and three, each about one third of an acre in size, were planted for the 1917 test. Plot one had grown peanuts continuously since 1910, while plot three had grown peanuts in 1911 and 1914.

It was observed that some of the supposed Virginia Bunch plants had a procumbent habit of growth, and when these plants began to blossom the suspicion that they were of the Virginia Runner variety was confirmed. As these two varieties are supposed to be merely selections of erect and procumbent types of plants from the same original variety, the presence of the Virginia Runner plants in the 1917 plantings might be due either to a slight mixture of the commercial seed, or a failure of the Virginia Bunch variety to be in all cases well fixed.

The two plots were under observation until the crop was harvested, November 9, 1917. During this time the writer found one Virginia Bunch plant in each plot which had wilted, and examination disclosed the coarse, white mycelium of *Scelerotium Rolfsii* about the base of the stems, thus indicating that the wilting was due to this fungus, as had been proven in many cases in 1916.

The fact that none of the Virginia Runner plants wilted confirms the data collected in 1916 to the effect that this variety is practically immune to the attacks of *Sclerotium Rolfsii.*

The resistance of the Virginia Bunch variety in 1917 was much greater than in 1916, as shown by the fact that in 1916, out of a

[1] McClintock, J. A., "Peanut-wilt caused by *Sclerotium Rolfsii,*" *Journal of Agricultural Research,* Vol. VIII., No. 12, pp. 441–448, March 19, 1917.

total of one hundred and thirty-two plants, six wilted; while in 1917, out of a total of more than seven thousand plants, on the same land only two wilted.

These data will possibly be of some value, especially to the Southern States, where the peanut promises to become a more important crop in the boll-weevil infested districts, and where *Sclerotium Rolfsii* has already become established as a serious parasite of numerous crops.

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THE BOSTON MEETING OF THE AMERICAN CHEMICAL SOCIETY. VII

Potash recovery from greensand and feldspar and by-products therefrom: H. W. CHARLTON. The process, stated briefly, consists in digesting greensand, feldspar, etc., with the requisite amount of lime and water at elevated temperatures and pressures. The alkali is brought into solution and recovered as a hydrate, and the solid material, which has undergone both chemical and physical change, is filtered off and employed as a binding material in the manufacture of brick, tile, artificial stone and other steam-hardened products. Possessing, as it does, self-cementing properties in addition to those induced by the steam-hardening treatment, it turns out materials which for strength and resistance to climatic conditions are superior to previously known steam-hardened products. Although the reaction may be applied to alkali-carrying silicates in general, it is believed that greensand is economically the most suitable, occurring, as it does, in unlimited quantities, obtainable without blasting or crushing and lying in stratified layers overlaid with a high silica sand. This is particularly fortunate as the overburden may be used with the resulting binding material in making brick, and the cost of mining is materially lessened. In the proportioning of the digestion mixture when using feldspar it is necessary to employ an equal weight or more of lime and eight times its weight of water, and to digest at pressures of from 200–250 pounds for from two to four hours. If the amount of water is reduced below this figure, the alumina in the feldspar appears to cause a reverting action. Fortunately this is not the case with greensand where the alumina is normally replaced by iron, and a double concentration can be employed. If lime is added in excess, there are no bad effects, as it is changed into a plastic sub-hydrate which in itself is a powerful binding material. It is undoubtedly true that the cementing material from a feldspar digestion is superior to that from greensand, but the cementitious properties of both are much superior to those now used in the production of steam-hardened products. Feldspar residue could be used in the manufacture of excellent face brick, whereas greensand residue would probably be better suited for the production of court or common brick, roofing, tile, drain tile, sewer pipe, fire-proofing, etc. Probably the most serious problem in the recovery of potash from feldspar is the separation of the soda. When employing greensand the almost complete absence of soda makes it possible to obtain a very pure caustic with one evaporation. Another objection to feldspar treatment is the almost invariable presence of alkali aluminates in the caustic liquor. It is found that there is not a trace in the greensand liquors. Although caustic alkali or a hydrated carbonate are the usual products of the recovery of the potash, other compounds may be easily formed as an end product. The same is true of the cementing material. Its use is not confined to the manufacture of brick. Other products such as tile, artificial stone, insulating material or stucco, are easily produced, and the choice depends on the market.

Some problems in the metallography of steel: H. M. BOYLSTON. (1) Banded structures in steel; their existence, cause and effect. Banded structure in nickel steel, in high manganese rifle-barrel steel, in shell forgings. Prevention and cure. (2) The hardening of high-speed steel and its relation to composition and performance. The Bellis microscopic test for determining best hardening temperature. Effect of carbon content. Effect of special elements. Streaky carbides. (3) The annealing of carbon steel castings. Results desired. Old methods. Present practise.

The effect of annealing on the electrical resistance of hardened carbon steels: I. P. PARKHURST. The object of the investigation was to anneal quenched steels over definite periods of time at constant temperatures. Five steels were determine the effect on electrical resistance of used varying in carbon content from 0.08 to 0.45 per cent. The temperatures used were 125° C., 175° C. and 250° C. The total periods of annealing varied from 90 to 190 hours. Results were plotted as time against resistance. Micro-photographs were made of the specimens during the

various stages of treatment. It was shown that while considerable variation in resistance could be produced by annealing, this variation was not accompanied by structural changes of a nature that could be easily detected under the microscope.

Thermophysics of zinc and its alloys: J. W. Richards. The author discusses some physical, particularly thermal, data which are lacking with respect to zinc and its chief alloys, brass and bronze, and calls attention to the great need of laboratory work to determine these constants. The data needed, such as vapor tensions at low temperatures, and latent heat of evaporation, are constants of nature, difficult to determine, yet of primary importance to the zinc industry if accurately determined and properly and intelligently used.

Recent developments in connection with the use of sulphur dioxide in hydrometallurgy: Edward R. Weidlein. The process developed by the author is based upon the precipitation of copper by means of sulphur dioxide. In precipitation, the solution is neutralized with lime and treated with sulphur dioxide until it has dissolved a percentage of gas equal to that of the contained copper. The precipitation of metallic copper ensues instantly when the solution is brought to a temperature of 160° C. under a pressure of 100 pounds. The mechanical arrangements are such that the processes of dissolution and precipitation are continuous. The copper assays, when melted, over 99 per cent. pure and contains oxygen as the sole impurity.

The importance of the flotation process in the metallurgy of copper; E. P. Mathewson. *Process revolutionary:* There is more ore handled daily by flotation than by any other non-ferrous metallurgical process. Prior to adoption of process the concentration losses were seldom less than 20 per cent.; now they are seldom over 8 per cent. Savings now so great that the so-called hold-up by owners of patents can not cripple the users of the process. *Process is a rule of thumb development:* The theory is now being worked out, but no wholly satisfactory theory has yet been evolved. Canadian users can afford to take chances on outcome of litigation, as they will only be compelled to pay reasonable royalties.

The theory of froth: Wilder D. Bancroft. Froth is a closely packed mass of bubbles having a cellular or honeycomb structure, the walls of the cells being liquid films. Froths are more stable, the more viscous the films; and the films can be made more viscous by adding solids.

Chemicals used in ore flotation: Oliver C. Ralston and L. D. Yundt. The use of certain chemicals in the flotation concentration of ores has been described and theories of the action of these chemicals have been explained. The use of chemical addition agents in ore-pulps during flotation is only in its infancy, and as the process is better understood operators will make greater use of chemical addition agents which will allow them to obtain the highest economic results. The possibilities of such applications are almost unlimited and it is probably along lines of this kind that some of the great advances in ore flotation will be made.

The selective action of cadmium salts on lead and zinc sulphides in flotation: M. H. Thornberry. The experiments so far completed show that the presence of cadmium salts practically stops lead sulphides from floating. The effect of these salts on zinc sulphides will be carried out in time to give results in the final paper.

Flotation experiments on zinc sulphide tailings, III.: W. A. Whitaker, S. F. Farley and H. P. Evans. (*a*) *The Effect of Certain Mixtures of Oils.*—A previous series of flotation tests carried out in this laboratory on a zinc sulphide tailing showed that the lighter wood distillates and certain vegetable oils displayed good selection for the mineral and yielded rich concentrates, while coal and wood tar mediums did not show such selection between mineral and gangue, but yielded high extractions. A series of tests was made in order to learn the effect of mixing a good "concentrating" medium with a good extracting medium, and of mixing certain lighter oils. (*b*) *The Effect of Organic Solvents.*—Solvents such as benzol, alcohol, kerosene, turpentine and gasoline were used with different oils in order to determine whether this method of emulsification would exert a favorable effect in flotation. The method was carried out under neutral, acid and alkaline conditions on tailings from the Joplin District. (*c*) *A Comparison between the "Mechanically Agitated" and "Pneumatic" Types of Flotation Machines.*—Several tests mentioned under (*a*) and (*b*) were made in machines of both types. The results obtained, as regards richness of concentrate and percentage extraction, were compared and plotted.